AN UNUSUAL NEW ELASMOSAURID PLESIOSAUR (SAUROPTERYGIA) FROM THE UPPER HAUMURIAN (MAASTRICHTIAN) OF THE SOUTH ISLAND, NEW ZEALAND

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An unusual new elasmosaur is described from postcranial elements preserved in a large concretionary mass from the Conway Formation (Haumurian; Maastrichtian) of the Waipara River area, North Canterbury, South Island, New Zealand. The specimen, representing the youngest plesiosaur described so far from New Zealand, is distinguished by characters of the pectoral girdle, particularly the elongate, rod-like ventral process and the symphyseal fossa on the fused coracoids. ❑ *Elasmosaur, Late Cretaceous, New Zealand.*

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A large concretion containing reptile bones was discovered on the left bank of the Waipara River, North Canterbury (Fig. 1B) in late 1982. The discovery was reported to Canterbury Museum and a team recovered the remains the following year. Preparation of the specimen over a period of several years revealed the almost completely disarticulated partial skeleton of an elamosaurid plesiosaur.

The area in which the specimen was found has produced fossil marine reptiles for many years. Indeed, New Zealand's first vertebrate fossils were reported from that area in 1859 (Hood, 1870). This started a golden age of fossil reptile discoveries in New Zealand, and extensive collecting by Hood, Haast, Hector and McKay led, by the mid-1870s, to the recognition of nine species of plesiosaur and two species of mosasaur (Hector, 1874). The bulk of these fossil remains came from exposures along the Waipara River and at Haumuri Bluff (Fig. 1B).

There followed a period of almost 100 years during which very few new discoveries were recorded. Then came the seminal work of Welles and Gregg (1971) in which they reviewed all the reptile material known at the time, provided a history of the early discoveries and described several new finds. They rationalised the plesiosaur material into a single acceptable taxon, the elasmosaur *Mauisaurus haasti* Hector, 1874, and placed many specimens as indeterminate except to family level at best.

More recent finds of marine reptiles, including plesiosaurs, have been made at Hawke's Bay (Fig. 1A: HB) in the North Island (Wiffen, 1980; 1990; Wiffen & Moisley, 1986) and at Shag Point (Fig. 1A: SP) near Dunedin (Cruickshank & Fordyce, 1996; 2002; Fordyce, 1983). Wiffen & Moisley (1986) provided the first description of skull material from a New Zealand plesiosaur and placed it in a new elasmosaurid genus, *Tuarangisaurus*. They attributed some post-cranial elements from the same locality to *Mauisaurus*. The large, substantially complete skeleton described from Shag Point by Cruickshank & Fordyce (2002) belongs to a new genus, *Kaiwhekia*, which has been placed in the Cryptoclididae by the authors. However, following recent cladistic analyses of plesiosaurs by O'Keefe (2001) and Gasparini et al. (2003b), some authors may dispute such a placement.

As rock enclosing the new specimen was gradually removed, it became clear that the neck and skull were missing but many diagnostic elements were present. It was also clear this specimen was unlike any previously recorded. In this paper we describe this new addition to the southwest Pacific Late Cretaceous marine reptile fauna.

MATERIAL

The specimen here described was preserved in a very large concretionary mass (estimated weight about 10 tonnes) that had broken into two very large blocks and a third much smaller one. The blocks were discovered where a portion of the cliffs overlooking the Middle Waipara River had slumped following a flood event.

After recovery, blocks were transported to Christchurch where they were further split, using drills and wedges, into smaller blocks that could be manhandled into the Canterbury Museum
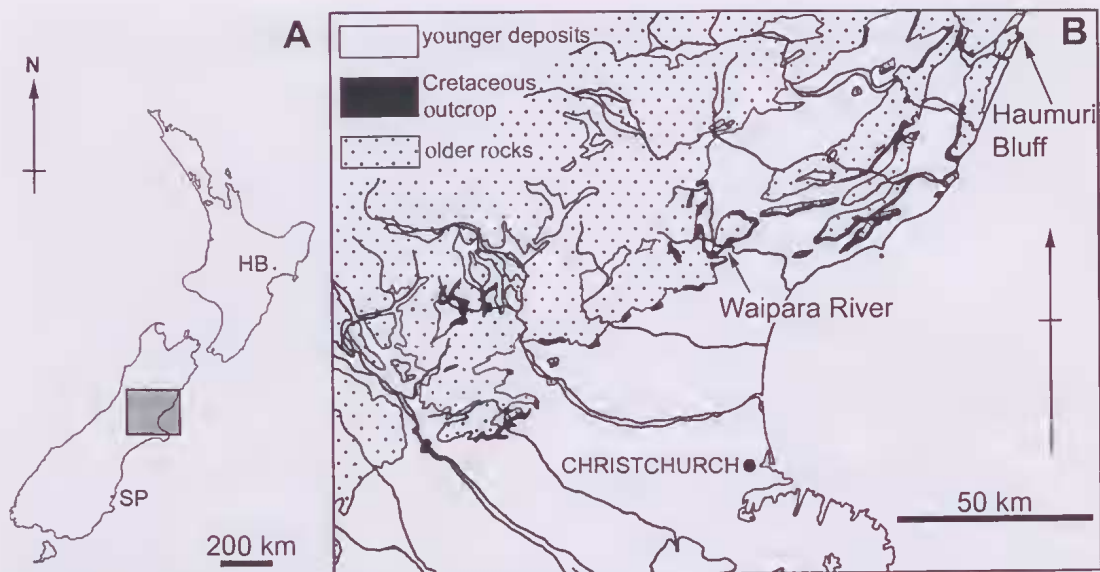
FIG. 1. Locality maps. A, map of New Zealand showing the locations of the North Canterbury region (shaded square), Shag Point (SP) and Hawke's Bay (HB). B, simplified geological sketch map of North Canterbury showing the Cretaceous outcrop and the locations of the Waipara River and Haumuri Bluff.

workshop. Although the matrix is calcareous, mechanical preparation was preferred over acid treatment as the separation between bone and matrix was good. Most bones were not removed completely from the matrix to preserve their context for a separate taphonomic study (Fig. 2).

CM Zfr 145 comprises an incomplete individual represented by the vertebral column from the anterior dorsal region to the tail, elements of the right fore limb and both hind limbs, major bones from the pectoral and pelvic girdles and an assortment of ribs and gastralia. Scattered among the bones are more than 340 gastroliths, mostly of resistant siliceous lithologies, in the size range 11-58 mm.

The preserved bones are scattered over an area of about 5 m^2; disarticulation is almost complete with only a few dorsal vertebrae retaining any original association. Disarticulation may have resulted from explosive degassing of a semi-buoyant carcass although some redistribution of bones probably occurred through the action of scavengers. Some vertical movement of small bones has taken place as a result of bioturbation.

Bones are generally well preserved with very little evidence of fragmentation or abrasion, suggesting a minimum of transport by current activity. However, several articulation surfaces,

such as the capitulum of both the femur and humerus, and a number of vertebral centra show marked degradation. Whether this is the result of chemical attack or bioerosion is difficult to determine, but it suggests that the bones were partially exposed for some time on the sea floor prior to burial.

AGE, STRATIGRAPHY AND GEOLOGICAL SETTING

The specimen was recovered from the Conway Formation, which crops out across a wide area of North Canterbury and southern Marlborough (Fig. 1B) and has been the main source of marine reptile fossils in the South Island. Throughout most of its outcrop area, the Conway Formation is a soft, easily eroded dark grey massive jarositic siltstone or silty sandstone in which pervasive bioturbation has all but obliterated primary sedimentary structures. Large subspherical calcareous concretions are a distinctive feature of the unit, particularly in the lower part. Warren & Speden (1978) estimated that about 25% of these concretions contain reptile bones at Haumuri Bluff, about 95 km northeast of the Waipara River (Fig. 1B).

The Conway Formation contains few macrofossils other than the reptile remains. In some places, where the siltstone has not been completely decalcified, a few species of molluscs
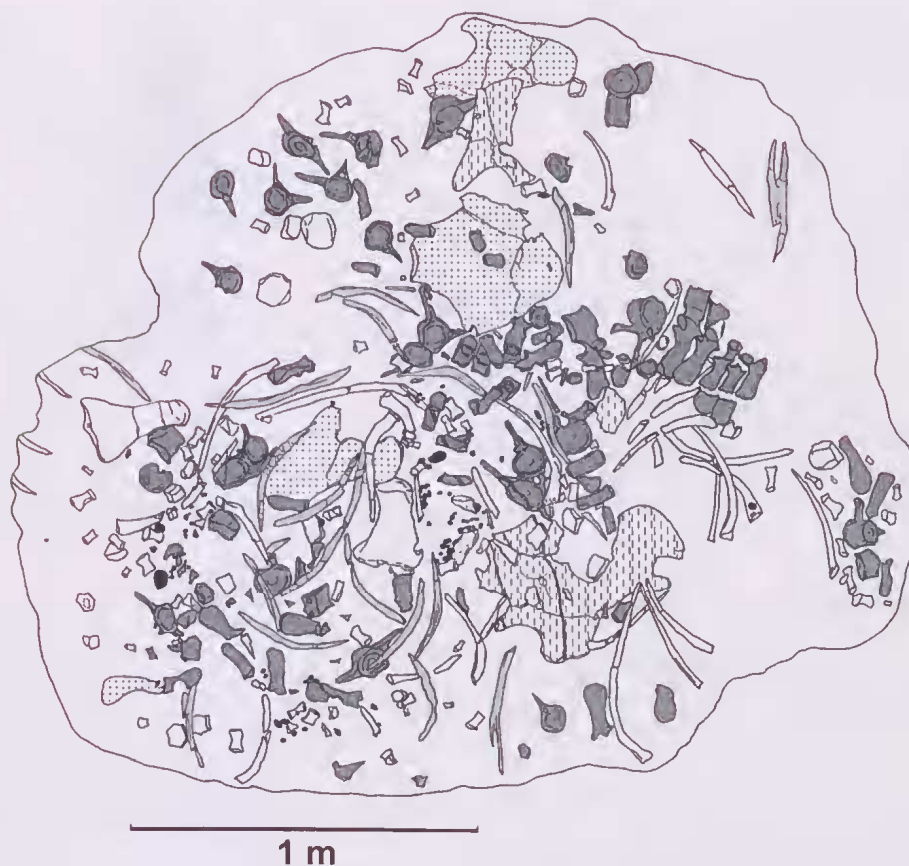
1 m

FIG. 2. Map of bone distribution of CM Zfr 145 in the concretion. Dark grey: vertebrae and neural spines; pale grey: gastralia; stipple: pelvic girdle elements; dashed: pectoral girdle elements; white: limb bones and ribs.

have been found, but generally calcareous shelled invertebrates, including foraminifera, are very rare and poorly preserved. Non-calcareous remains, such as phosphatic-shelled brachiopods, sharks' teeth, teleost bones and scales, and plant material, are present but uncommon. However, rich dinoflagellate assemblages are present.

Sedimentary and geochemical characteristics of the Conway Formation suggested to Warren & Speden (1978) that it was deposited in an area of sea floor free from strong current or wave activity in which oxygen-poor conditions prevailed. They favoured a barred submarine depression or series of depressions, as the depositional setting and drew analogy with the present day Santa Barbara Basin off California.

The Conway Formation is generally regarded as belonging within the Haumurian Stage of the local New Zealand time scale, although Browne & Field (1985) suggested that it might range up into the overlying Teurian Stage. The Haumurian Stage was once correlated with the Maastrichtian Stage on the European time scale (Wellman, 1959) but more recently has been shown to be the equivalent of the Upper Santonian to end-Maastrichtian portion of the international scale (Crampton et al., 2000). The revised correlation is based, in part, on the development of a refined biostratigraphy founded on dinoflagellates (Roncaglia & Schiøler, 1997; Roncagli et al., 1999; Schiøler & Wilson, 1998). Application of this biostratigraphical scheme to the Conway Formation shows it to range from lower Middle Campanian at Haumuri Bluff in the north to Upper Maastrichtian at Waipara River

(Roncaglia and Schiøler, 1997; Roncagli et al., 1999) (Fig. 3). Recently, Wilson et al. (in press) have used dinoflagellates to date individual reptile specimens within this scheme.

SYSTEMATIC PALAEONTOLOGY

Class REPTILIA Linnaeus, 1758
Order SAUROPTERYGIA Owen, 1860
Suborder PLESIOSAURIA de Blainville, 1835
Superfamily PLESIOSAUROIDEA (Grey, 1825) *sensu* Welles, 1943
Family ELASMOSAURIDAE Cope, 1869

Elasmosaurid indet.

MATERIAL. CM Zfr 145 from the Conway Formation on the left bank of Middle Waipara River about 1 km upstream from the old Laidmore Bridge (New Zealand Fossil Record File No. M34/f462).Upper Haumurian (Late Maastrichtian) *Manumiella druggi* zone (Wilson et al., in press) (Fig. 3).

DESCRIPTION. The skeleton is interpreted as belonging to a 'young adult'. The neural arches of some dorsal and caudal vertebrae appear firmly fused to their centra but among the bones there are dissociated neural arches that clearly are not fused to centra. This would place the specimen between the 'juvenile' and 'adult' categories defined by Brown (1981). The specimen lacks the skull, cervical vertebrae and the major limb bones from the left side (Fig. 4).

An estimate of body length indicates the animal to have been a minimum of about six metres long in life. This is based on an estimate of 2 m for the trunk, 1 m for the tail and an assumption that the neck makes up about one-half of the total body length.

Axial skeleton. Seventeen dorsal vertebrae, three sacral vertebrae, 30 caudal vertebrae and 16 dissociated neural spines are present. Dorsal vertebrae typical of an elasmosaur, with subcircular articular faces on reel-like centra (Fig. 5A-B). Where measurements are possible,
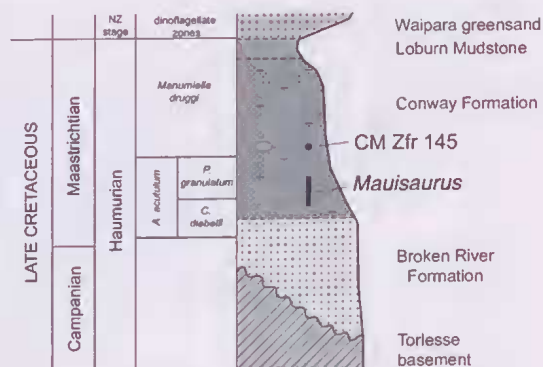

FIG. 3. Stratigraphic section of the Cretaceous sequence exposed in the Waipara River showing levels from which the elasmosaurs *Mauisaurus* and CM Zfr 145 have been recovered. (follows Roncaglia et al., 1999 and Wilson et al., in press).

dorsal vertebrae show vertebral length indices (Brown, 1981) in the 0.75 – 0.77 range. Both anterior and posterior zygapophyses are separated pairs.

Sacral vertebrae have transversely ovoid articular faces (Fig. 5C) and in each case the sacral ribs, which taper distally, are firmly fused to the centra. Two nutritive foramina are present on the ventral surface of each.

Anterior caudal vertebrae are similar in shape to the sacrals, although a little shorter, but further back in the series they become more hexagonal in cross-section (Fig. 5D), with the smallest examples being almost cylindrical. Anterior centra have two ventral foramina but this is reduced to one further back in the series. Chevron facets are not seen on the anterior caudal vertebrae but are well developed on the more hexagonal centra, at the posterior end of low rounded ventral ridges (Fig. 5E). Caudal ribs are

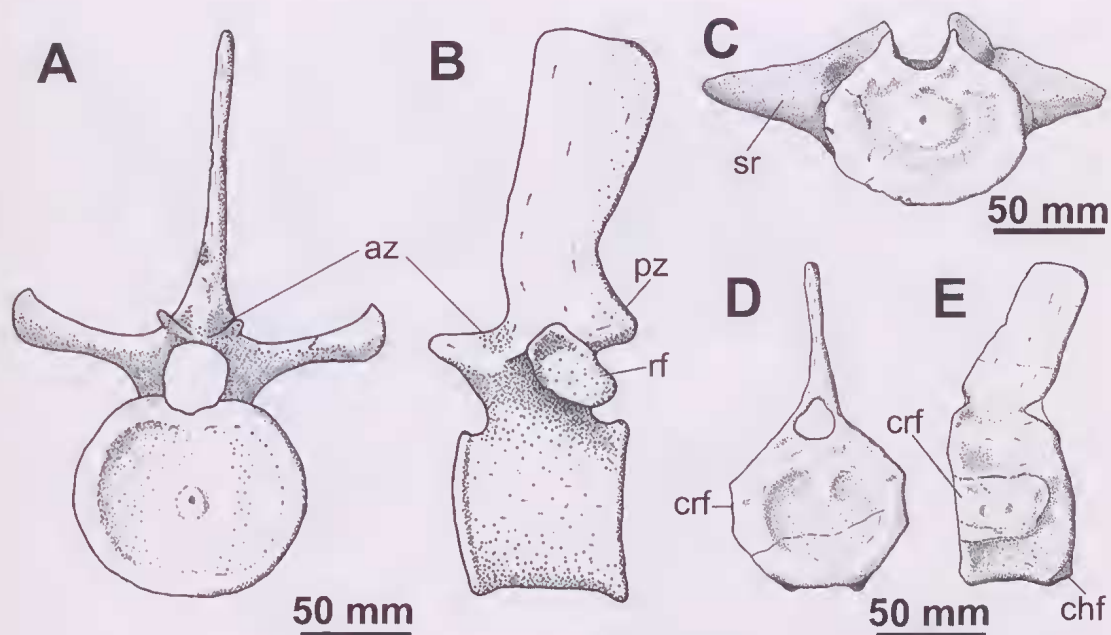FIG. 4. Diagram showing (in black) the bones represented in CM Zfr 145.

FIG. 5. Dorsal, sacral and caudal vertebrae of CM Zfr 145. A, restored mid-dorsal (based on three actual examples) in anterior view. B, restored mid-dorsal in left lateral view. C, sacral in anterior view showing firmly attached sacral ribs. D, caudal in anterior view. E, caudal in left lateral view. Abbreviations: az, anterior zygapophyses; chf, chevron facet; crf, caudal rib facet; pz, posterior zygapophyses; rf, rib facet; sr, sacral rib.

short (maximum length about 120 mm), about 25-30% as wide as long, flat with parallel sides and rounded distal terminations.

Girdles. In the pectoral girdle, the right scapula, complete right coracoid and partial left coracoid are preserved. As in other New Zealand plesiosaurs, no clavicles or interclavicles have been recognised. Possibly these were cartilaginous and not preserved.

Scapula characteristically a triradiate bone with the angle between the ventral and dorsal rami, measured at the ridge on the ventral surface where they meet, being about 140° (Fig. 6D). Dorsal ramus is a relatively short, tapering blade-like structure with a rounded distal margin (Fig. 6A-C). Ventral ramus has a subrectangular outline and is gently convex upwards (Fig. 6A-C). Although it may have suffered some damage, very little seems to be missing from the bone. The square anterior margin suggests that a clavicle may have been present in life.

In outline, coracoids show the typical "hour-glass" shape seen in elasmosaurs (Fig. 7). They meet and are firmly fused along the anterior portion of the symphysis, which extends forwards beyond the level of the glenoids as an elongate anterior process (Fig. 7A). This process projects steeply downwards anteroventrally (Fig. 8 C-C'). It does not seem likely that a full midline bar was developed in this specimen. Fusion of the coracoids is complete with no suture visible between the right and left portions. On the ventral surface, about midway along the anterior symphysis, a prominent cylindrical process, buttressed by ridges, extends ventrally (Fig. 7B-C). Posteriorly, the coracoids are separated by a large heart-shaped intracoracoid foramen. The dorsal (visceral) surface of each coracoid is flat, with no sign of any transverse thickening of the bone between the glenoids. An unusual feature of the pectoral girdle is that the dorsal surface of the conjoined coracoids is cleft by an elongate boat-shaped trough (Fig. 8). This trough, here named the symphyseal fossa, extends from just behind the anterior process to a point posterior of the ventral process. It is unclear just how far back this feature is present, but it is believed to be connected to an elongate oval foramen that opens on the ventral surface of the coracoids posterior of the ventral process (Fig. 7A).
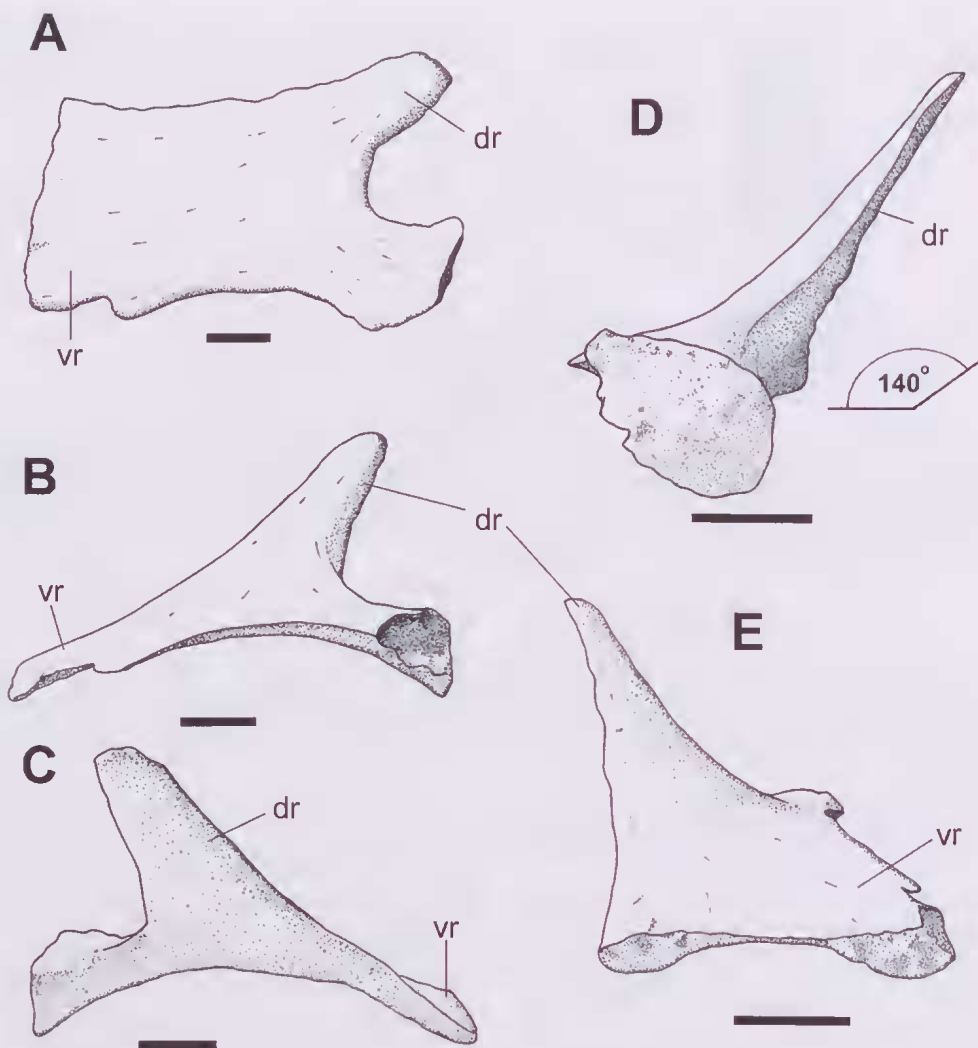
FIG. 6. Right scapula of CM Zfr 145. A, dorsal view. B, internal lateral view. C, external lateral view. D, posterior view. E, anterior view. Note slightly different scales; scale bars = 50 mm. Abbreviations: dr, dorsal ramus; vr, ventral ramus.

The pelvic girdle is represented by both ilia, both ischia and the left pubis (Fig. 9). Ilia (Fig. 9A) are robust curved rods with expanded proximal (ventral) ends bearing facets for junctions with the ischia and acetabula. Their distal (dorsal) ends are parallel sided with 'square' terminations.

The pubis (Fig. 9B) is a large subquadrate plate-like bone, thickest at the acetabulum and very thin in its central part. The lateral and posterior margins are concave; the anterior and medial margins are gently convex.

Ischia (Fig. 9C) are elongate "hatchet-shaped" plates in which the maximum width, measured at right angles to the median line, is about three-quarters of the maximum length. Their ventral surfaces are almost planar while the dorsal surfaces have a broad convex ridge extending from the symphysis towards the lateral ramus. Along the symphysis, each ischium bears a short anterior projection with a 'square'
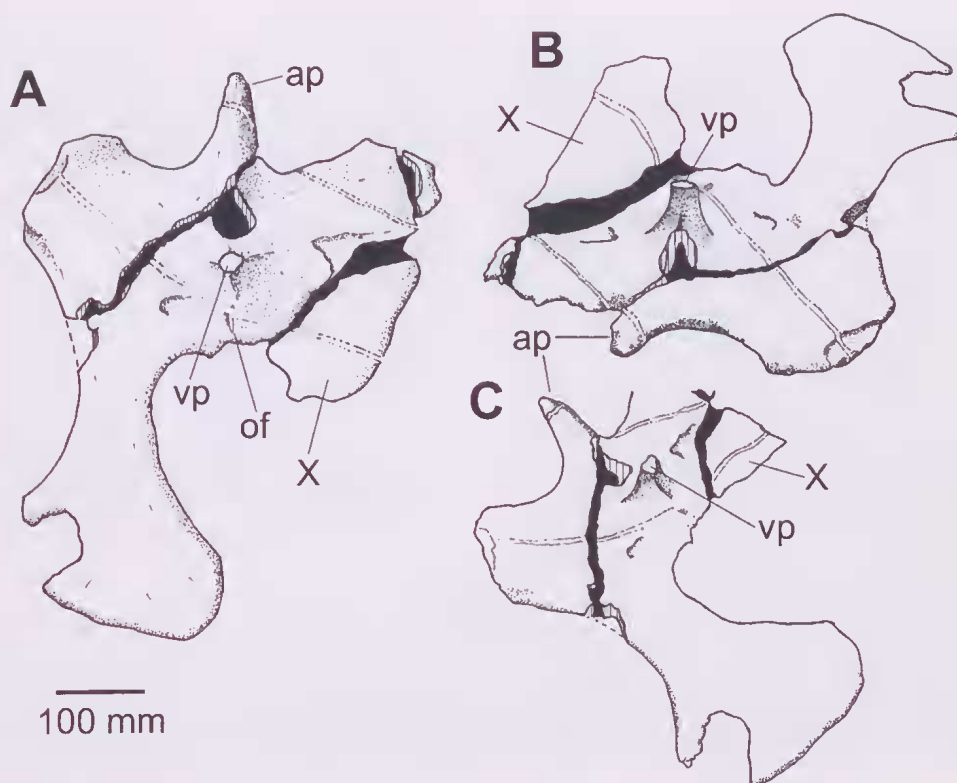
FIG. 7. Coracoids of CM Zfr 145. A, ventral view. B, anteroventral view. C, posteroventral view showing the preserved outlines and the rod-like ventral process. Fragment X does not lie in the same plane as the rest of the bone. Abbreviations: ap, anterior process; of, elongate oval foramen; vp, ventral process.

termination. These projections do not extend as far forward as the facet where the ischium meets the pubis. In life, the ischia and pubes sloped upward and outward from the symphysis to form an upwardly concave visceral cup (Fig. 10E). Restored outlines of both pectoral and pelvic girdles are presented in Fig. 10.

Limbs. Limb elements are not in association, making identification of those distal to the epipodials difficult. The right humerus, right femur, four epipodials from three limbs, 15 metapodials and 77 phalanges are scattered among the other bones. Humerus (Fig. 11) has a width/length ratio of about 82% and the femur (Fig. 12) about 73% but each has a damaged capitulum and so maximum length is difficult to measure accurately. The femur is slightly longer and more slender than the humerus, which has a more markedly asymmetrical outline.

Among the epipodials are one radius, two tibiae and a fibula. In the fore paddle, we can only identify one radiale of the proximal carpal bones, two distal carpals that we have designated dcIV, and a metacarpal identified as mc1. In the hind paddles, the proximal tarsals are represented by both tibiales, both centrales and a fibulare. Four distal tarsals have been identified, two of which are designated dtII+III, one as dtI and one as dtIV. Two metatarsals are identified as mt1. A partial reconstruction of the right rear paddle based on the elements recognised is given in Fig. 12.

REMARKS. It was deemed inadvisable to establish a new taxon without skull material but we believe that the features of the postcranial skeleton serve to separate CM Zfr 145 from all previously described elasmosaurs. In particular, characters of the pectoral girdle can be used to distinguish the new form. In addition, the ischia seem to be unusually long compared with those of other Late Cretaceous elasmosaurs.
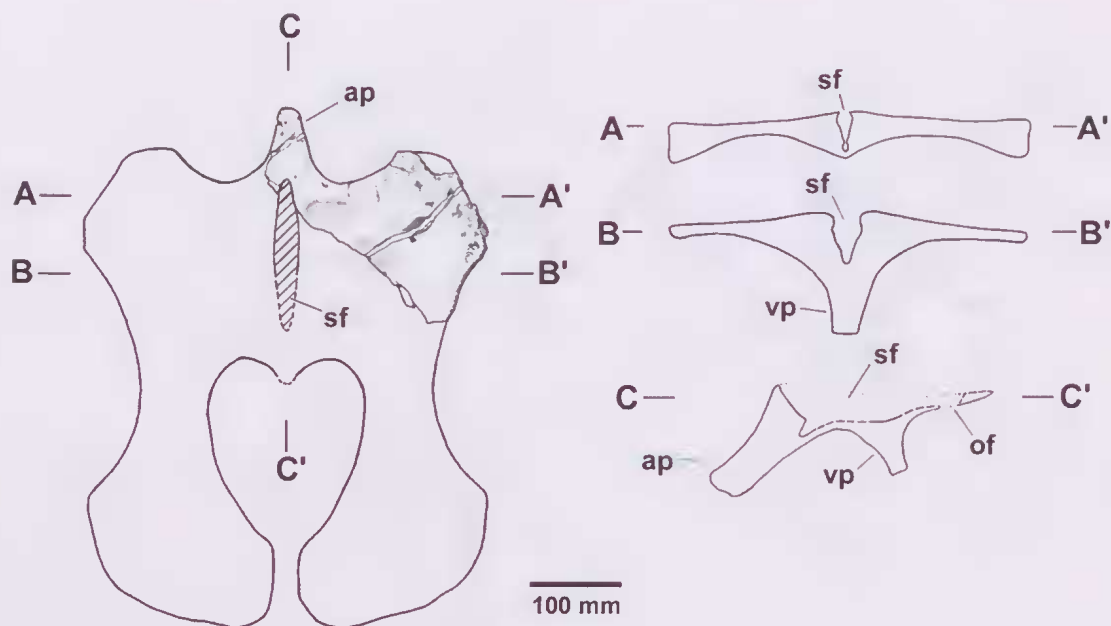
FIG. 8. Restoration of the dorsal surface of the coracoids showing the position and supposed extent of the symphyseal fossa, and transverse and longitudinal cross-sections illustrating the shape of the feature. Abbreviations: ap, anterior process; of, elongate oval foramen; sf, symphyseal fossa; vp, ventral process.
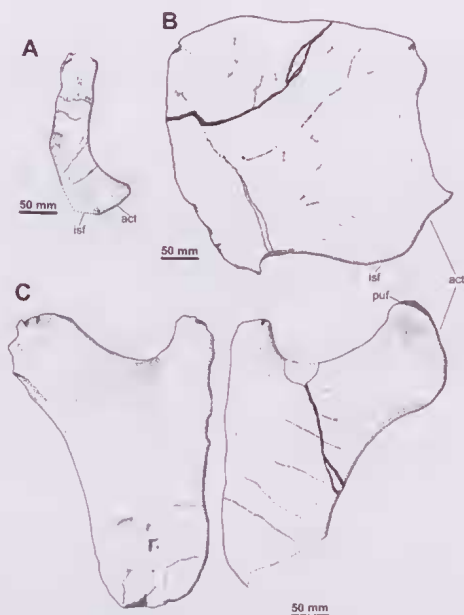

FIG. 9. Pelvic girdle elements of CM Zfr 145. A, right ilium in lateral view. B, right pubis in ventral view. C, ischia in ventral view. Abbreviations: act, acetabulum; isf, ischial facet of ilium and pubis; puf, pubic facet of ischium.
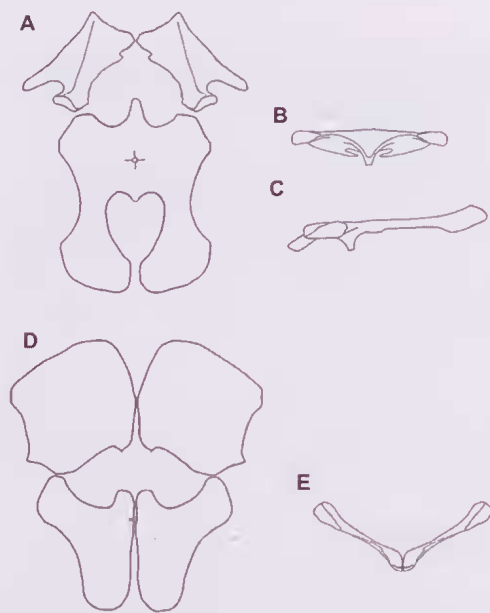
FIG. 10. Reconstructed outline of the pectoral and pelvic girdle elements. A, ventral view of scapulae and coracoids. B, anterior view of coracoids. C, left lateral view of coracoids. D, ventral view of pubes and ischia. E, anterior view of ischia.
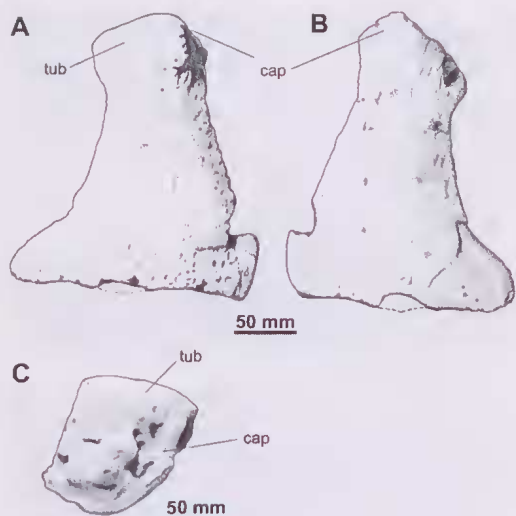
FIG. 11. Right humerus of CM Zfr 145. A, dorsal view. B, ventral view. C, proximal end view. Note damage to capitulum. Abbreviations: cap, capitulum; tub, tuberosity.

Of the two previously described New Zealand elasmosaurs, both of which are slightly older than CM Zfr 145, only *Mauisaurus haasti* Hector, 1874 can be directly compared with the new taxon. The other, *Tuarangisaurus keyesi* Wiffen & Moisley, 1986, is known only from its skull and several anterior cervical vertebrae. A new description of *M. haasti*, based on a more complete specimen than previously available, has recently been prepared by Hiller et al. (in press). This shows that the scapulae and coracoids are quite different from the same bones in CM Zfr 145. In *Mauisaurus*, the angle between the dorsal and ventral rami of the scapula is 130°, the dorsal ramus has parallel sides and has a square termination, and the ventral plate has a convex anterior margin. In CM Zfr 145 the angle between dorsal and ventral rami of the scapula is 140°, the dorsal ramus tapers distally and has a rounded termination. The ventral plate has a straight anterior margin.

The coracoids of CM Zfr 145 are particularly unusual. They are firmly fused anterior of the intracoracoid foramen, unlike the situation in *Mauisaurus* and many other elasmosaurs where the coracoids remain separate, even in very mature adults. They are flat and plate-like and show no signs of the transverse thickening observed on the dorsal surface of the coracoids in

Mauisaurus. On the ventral surface, they bear an elongate rod-like projection quite unlike the rounded conical ventral process of *Mauisaurus* and some other elasmosaurs. Indeed, this feature is unknown in any elasmosaur described so far, although we have been made aware of an undescribed specimen in Canada that shows a similar feature (E. Nicholls, pers. com.). The Canadian specimen differs from CM Zfr 145 in that although its coracoids may be fused they have a distinct suture between the two halves (P. Druckenmiller, pers. com.). Also, the posterior ends of the coracoids of the Canadian specimen differ markedly in shape from those of CM Zfr 145. Another unusual feature of the coracoids in CM Zfr 145, not reported from any other elasmosaur, is the symphyseal fossa on the dorsal surface. Conceivably, this might be interpreted as an area of incomplete fusion, still occupied by cartilage, along the inter-coracoid contact. However, given the intimate fusion of the coracoids, which must have occurred at a very early ontogenetic stage, it seems more likely that the symphyseal fossa is a real character. This interpretation is supported by the 'clean' edges of the feature (Fig. 13), although there has been some post mortem modification of the walls of
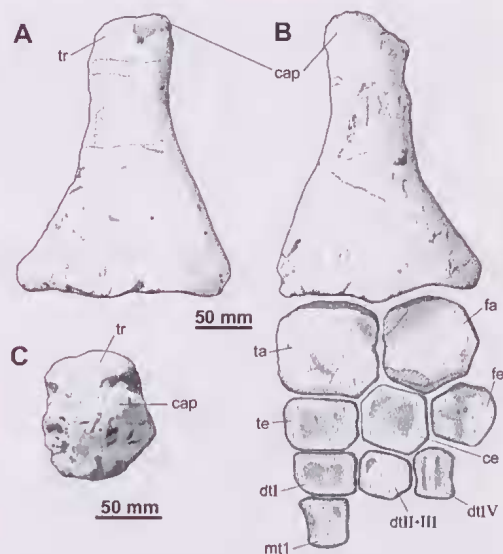

FIG. 12. Right hind limb of CM Zfr 145. A, dorsal view of femur. B, ventral view of femur and paddle elements. C, proximal end view. Note damage to capitulum. Abbreviations: cap, capitulum; ce, centrale; dt, distal tarsal; fa, fibula; fc, fibulare; mt, metatarsal; ta, tibia; te, tibiale; tr, trochanter.
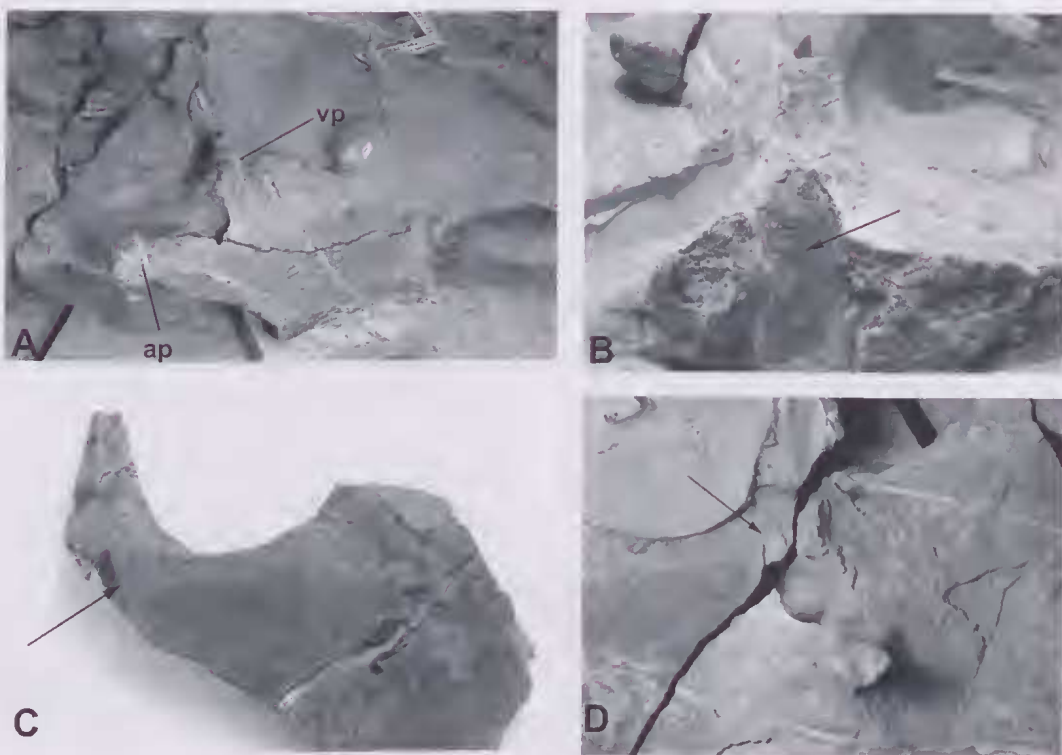
FIG. 13. Photographs of fused coracoids, CM Zfr 145. A, oblique view ; ventral surface of coracoids showing the elongate anterior process (ap) and the pillar-like ventral process (vp). Hole immediately anterior of ventral process is a drill hole used in splitting the blocks. Right anterior portion of the coracoid detachable and seen inverted in C. B, close-up of ventral process with view of internal structure afforded by drill hole. Note sediment fill of symphyseal fossa (arrowed) and lack of suture along midline. C, dorsal view of detached portion of coracoid showing anterior margin of symphyseal fossa (arrowed). Note lack of suture along midline. D, close-up of area from which right anterior portion of coracoid has been removed and showing imprint of anterior end of symphyseal fossa (arrowed).

the fossa as has occurred in other bones while they lay exposed on the sea floor.

Comparisons with other Late Cretaceous austral elasmosaurids are made difficult by the incompleteness of the specimens. Chatterjee & Small (1989) described a number of indeterminate elasmosaurids, represented by postcranial remains, from Seymour Island, Antarctic Peninsula. Three of their specimens preserve parts of the pectoral girdle. They show that the coracoids were not fused and on the ventral surface a transverse ridge extends from the glenoid to the median symphysis, a feature not seen in CM Zfr 145.

Gasparini et al. (2003a) described several specimens from northern Patagonia, drawing similarities between them and other New Zealand taxa. One of their specimens, *Tuarangisaurus? cabazai*, is evidently a juvenile but the characters of its coracoid immediately distinguish it from CM Zfr 145. Their other specimens, assigned to cf. *Mauisaurus* sp., preserve very few girdle elements but the ilia appear very different to those of CM Zfr 145. They are gently curved and lack the distinct knee seen in those of CMZfr 145.

We conclude that, in spite of its incompleteness, CM Zfr 145 represents a distinctive new elasmosaur and adds to the Late Cretaceous radiation of marine reptiles in the southwest Pacific.

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